

GPS/Inertial Micro-Camera for Oceanographic Properties and Shallow Water Hydrography

**Joint Navigation Conference 2009
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Session A1: Warfighter Requirements & Solutions

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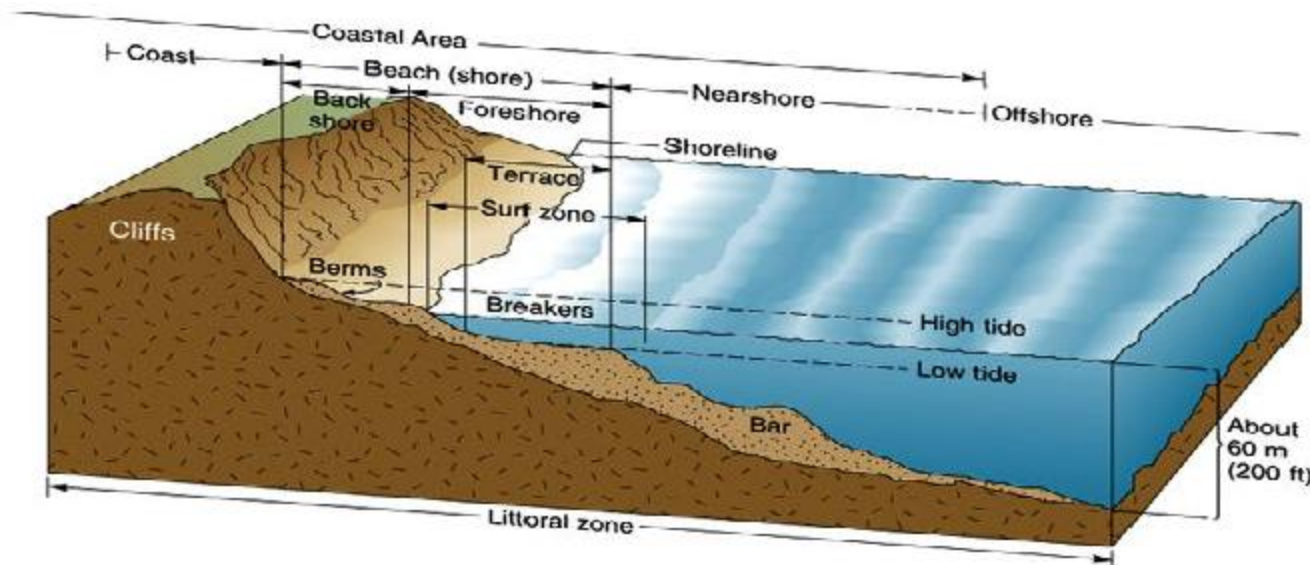
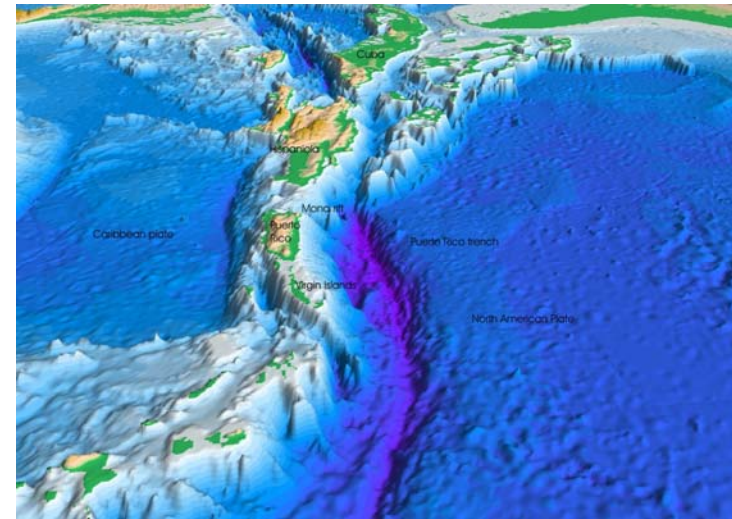
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Overview

- Problem Statement
- Micro-Camera System
 - Payload
 - Image Processing / Ground Station Software
 - Bathymetry Software
- Test Results

Bathymetry is the underwater equivalent to topography

Littoral Zone is the ocean region extending from the high water mark to the shoreline areas that are permanently submerged



Key Technical Challenge



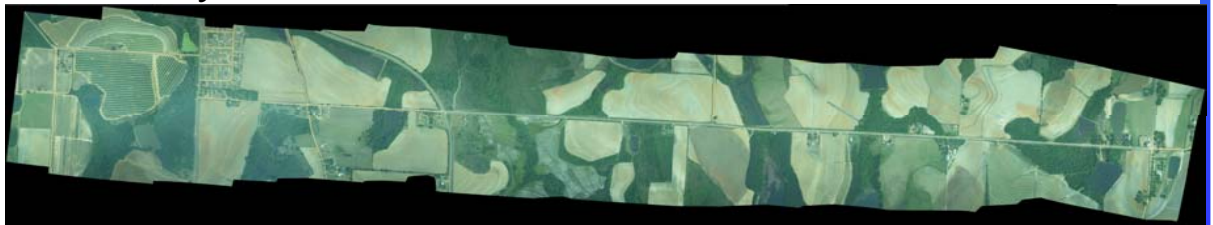
Typical Tier I UAV

- Current AROSS system has proven use of registered imagery for depth inversion
- Naval METOC officers deployed with Special Operations teams need organic capability to recon multiple beaches and collect water depths
- Key challenge is for reduced SWAP payload to fit on small Tier I UAV
- Range: 10 km
- Endurance: 2.5 – 9 hours
- Airspeed: 25-50 km/hr
- Nominal payload weight: 600 - 900g
- Power: 6 -12 W

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Military & Civilian Need for UAV Based Bathymetry/Mapping/Targeting

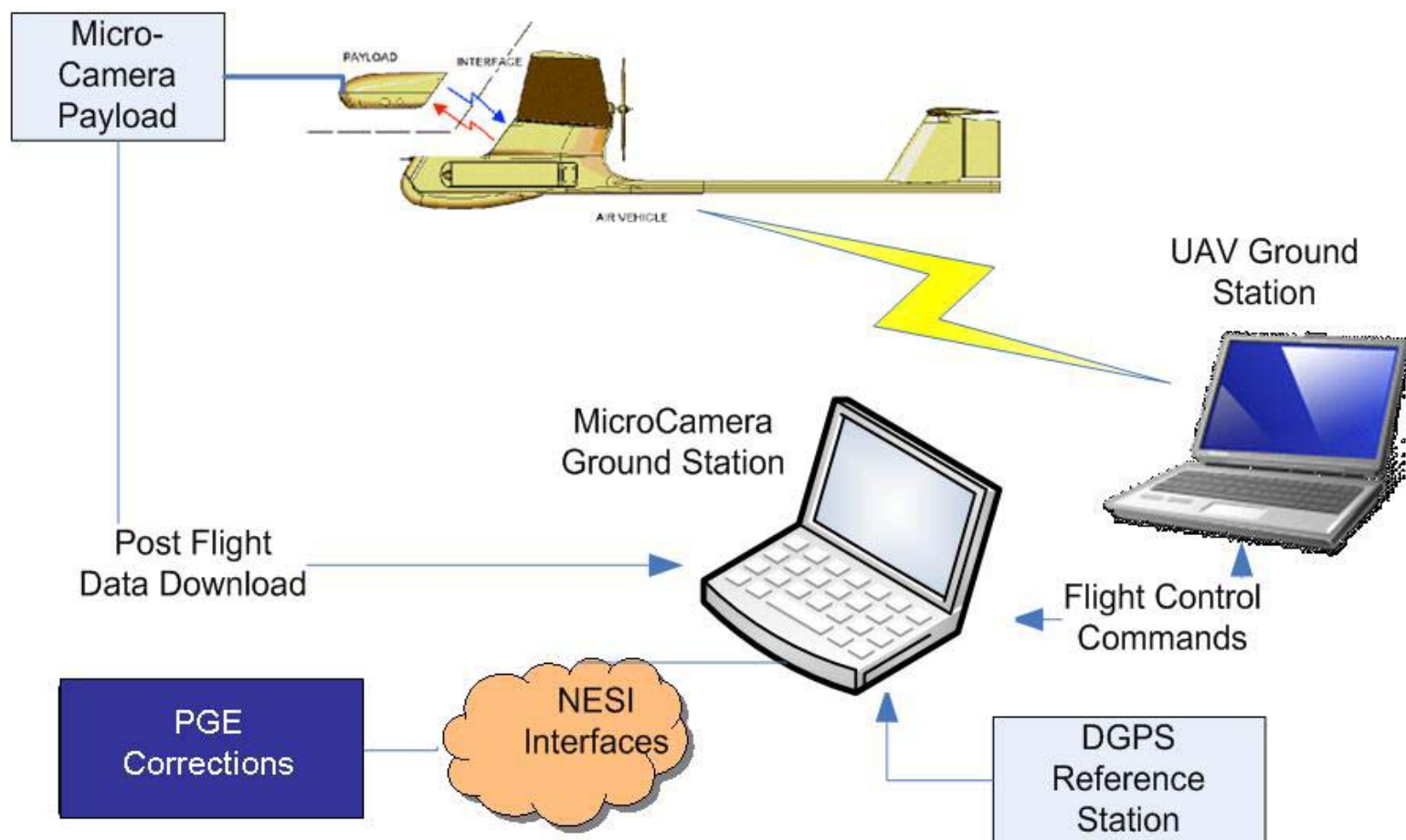
- Bathymetry
 - Army Corp of Engineers
 - High resolution shoreline data for modeling for forecasting
 - Littoral Battlespace Sensing, Fusion, and Integration (LBSF&I)
 - Bathymetry surveys critical for weather modeling and mission planning operations
 - Naval METOC Personnel
 - Bathymetry data from shallow regions in support of littoral operations
- Mapping/Targeting
 - NOAA and NGA
 - Military Mission Planners
 - Near real-time targeting data/Bomb Damage Assessment
- Civilian Commercial Applications
 - Low-cost Rapid Coastal Surveys
 - Precision Land Maps
 - Wave Modeling



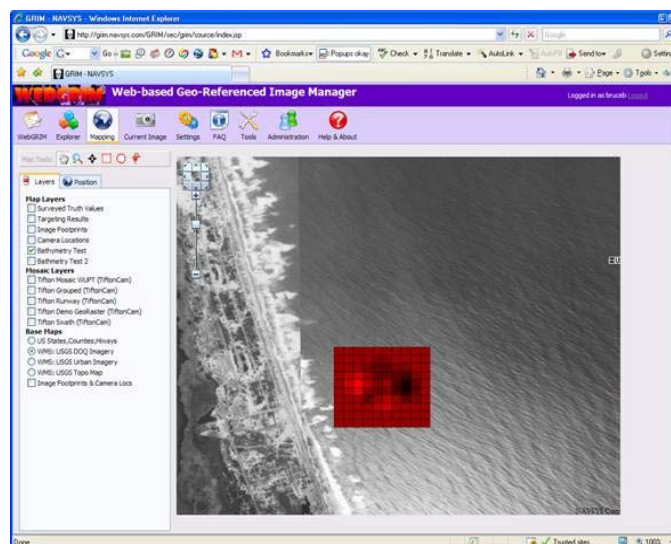
GPS/INS Requirements

- Why is bathymetry processing so difficult in a small UAV?
 - Region of Interest
 - 1 km x 5 km shoreline
 - Bathymetry grid - 100 m x 100m cells
 - Imaging Requirements
 - Image capture at 2 Hz over region of interest
 - $\frac{1}{2}$ pixel smear (objective) and $\frac{1}{5}$ pixel smear (Goal)
 - Average resolution of 1 meter/pixel
 - Absolute ground accuracy
 - Under 10 meters (objective) – Under 2 meters (Goal)
 - No need for ground control points
 - Relative accuracy of points sampled at same time in different ground images should be +/- 1 meter
 - Time over target for Bathymetry SW to estimate wave number
 - ~240 consecutive images of area of interest
 - Tier I UAV Payload size
 - Most UAVs are battery powered w/limited power available for the payload
 - Payload weight limited to ~ 2 lbs

NAVSYS Micro-Camera



Micro-Camera CONOPS



Operator designates AOI using WebGRIM Interface on Micro-Camera Ground Station Laptop

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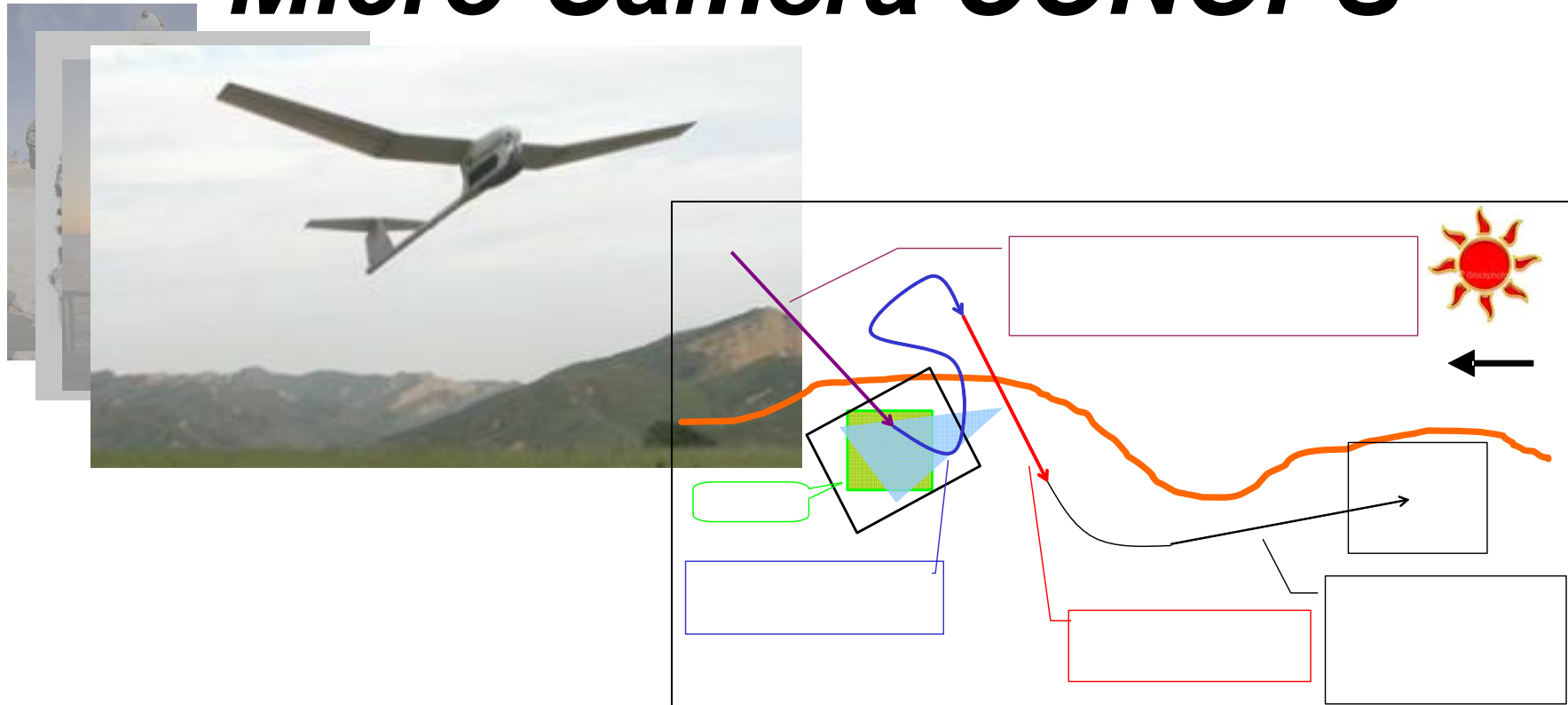
Micro-Camera CONOPS



Operator launches the UAV

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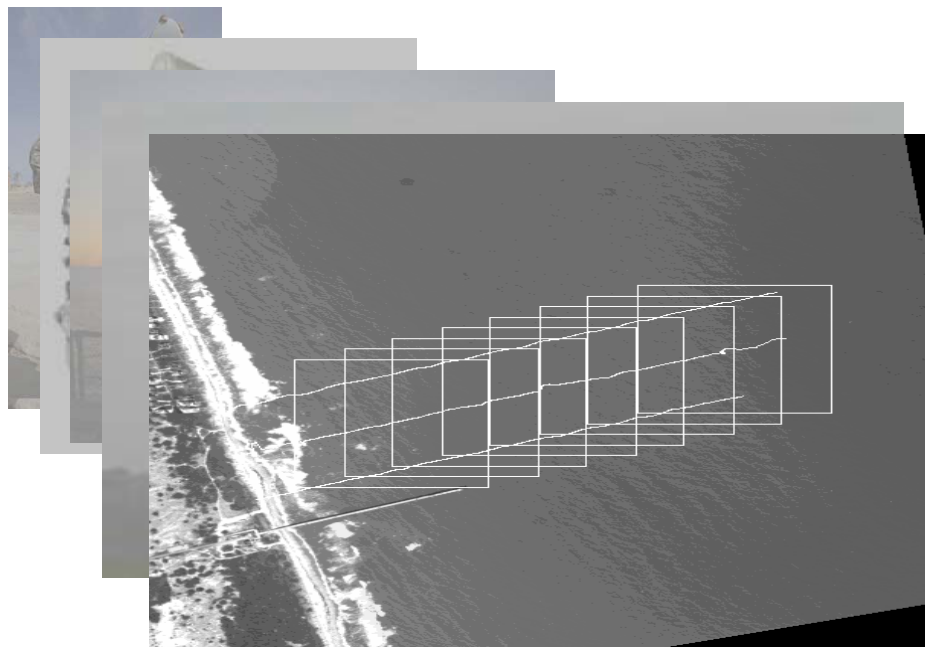
Micro-Camera CONOPS



- Micro-Camera payload measures winds aloft en route to AOI
- Micro-Camera Ground Station flight planning module calculates flight path waypoints over AOI based on sun angle and wind direction and sends updated flight plan to UAV

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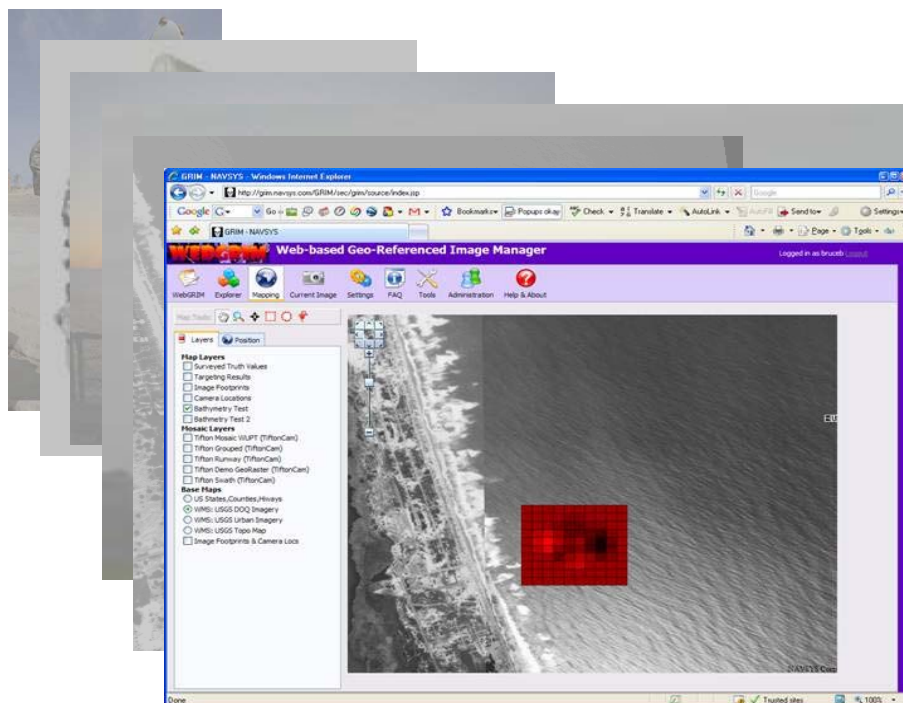
Micro-Camera CONOPS



UAV captures images
over AOI

- Imagery and GPS/INS data logged in payload for post processing
- Thumbnails sent to Micro-Camera Ground Station during flight so operator can monitor image quality

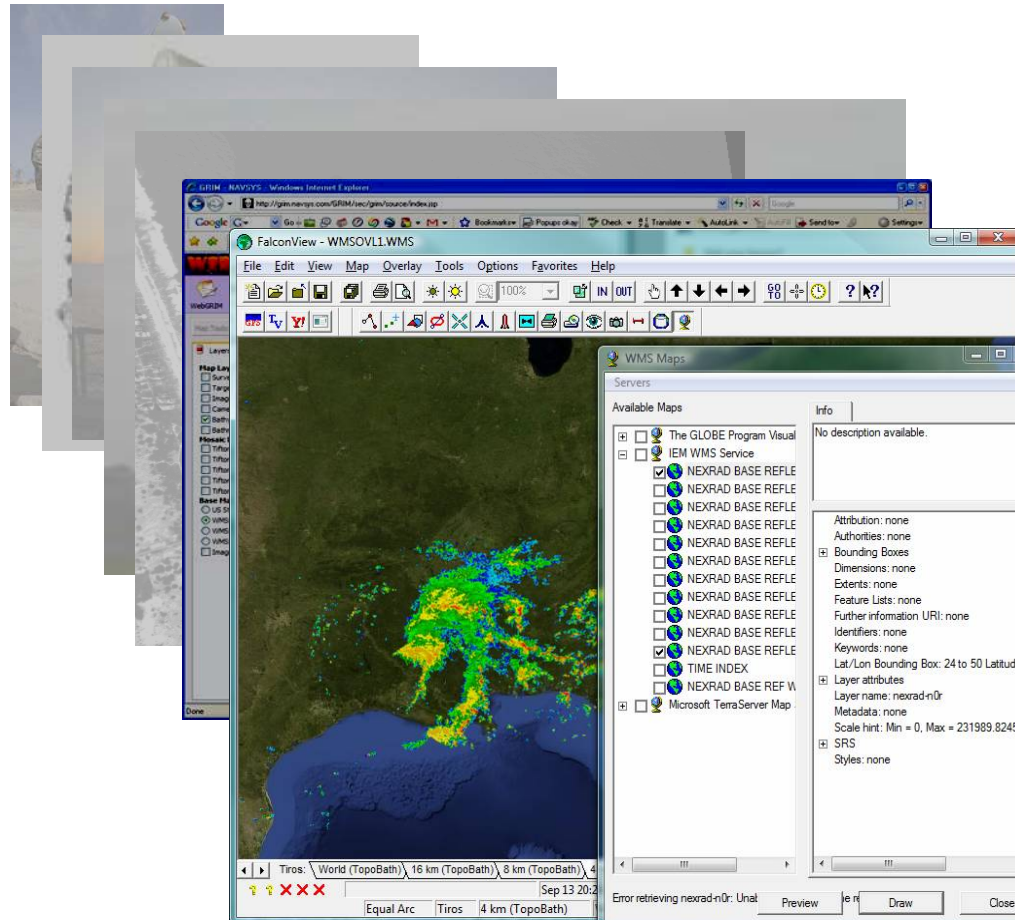
Micro-Camera CONOPS



Ground Station Post Processing

- Operators retrieve UAV
- GPS/IMU and imagery data transferred from payload compact flash to ground station
- DGPS data collected from on-site reference station
- InterNav processing
- Image Processing (Ortho)
- Image Selection/Stacking
- DepthWizard
- WMS Publishing

Micro-Camera CONOPS

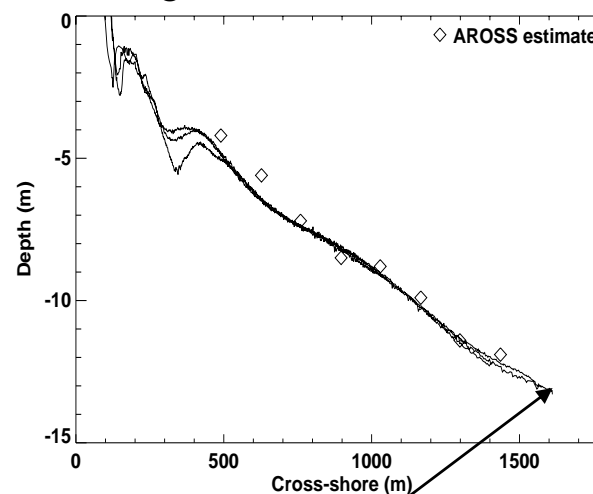
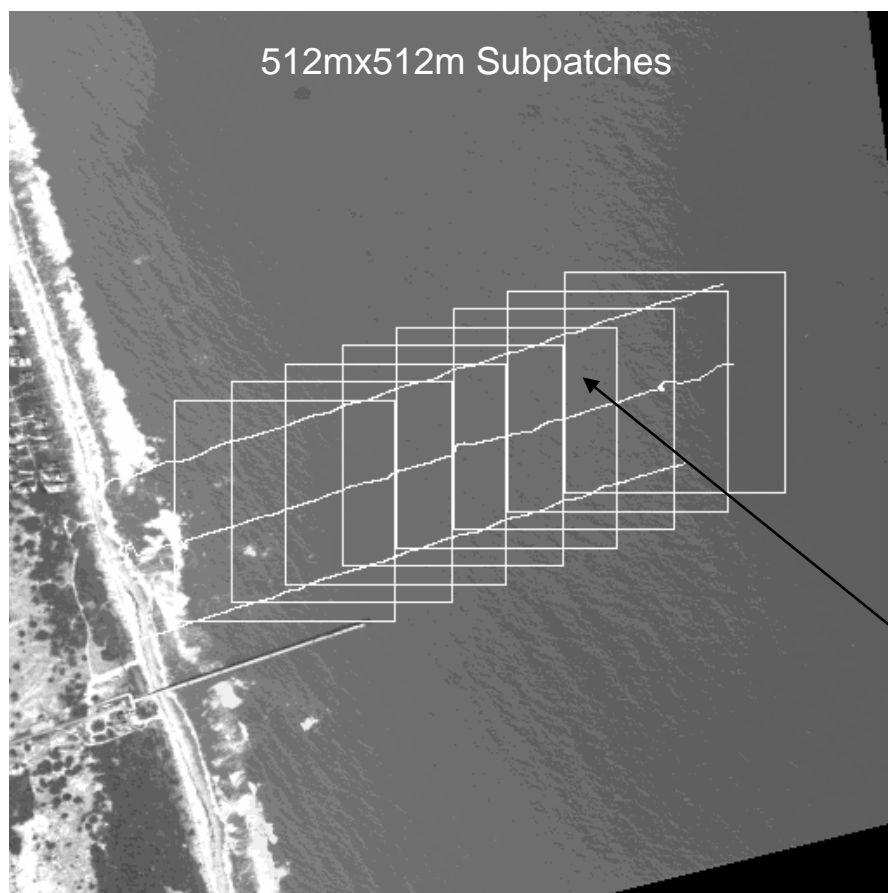


Under NESI
guidance data is
made available to
other applications via
a WMS data feed

Cross-Shore Bathymetry Profile

Errors using mean depth in subpatch:

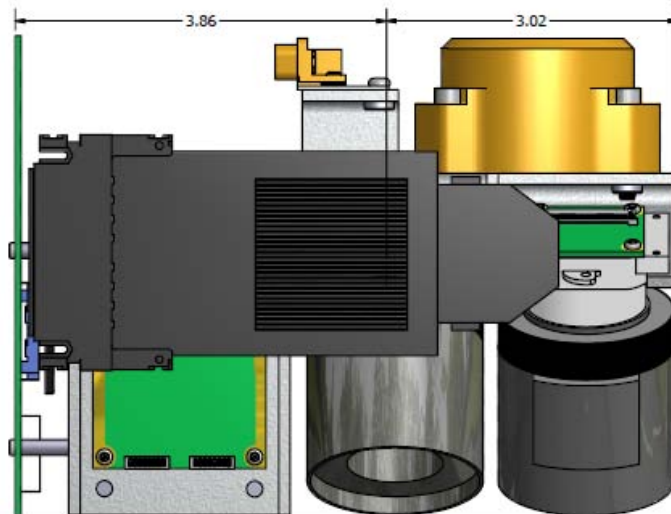
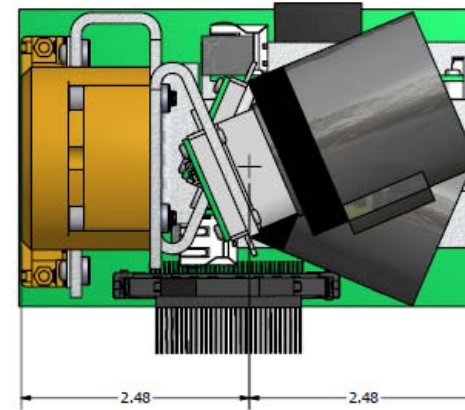
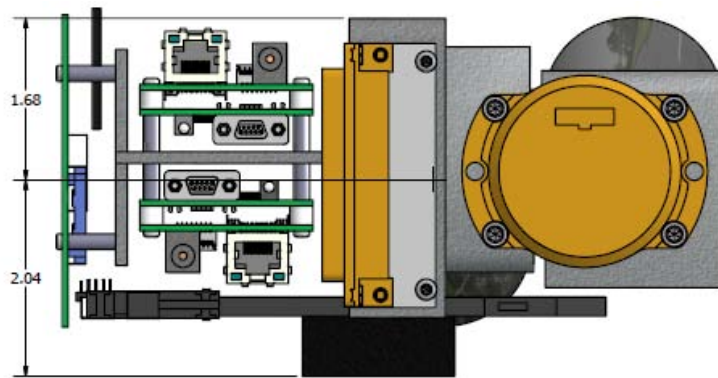
- Bias = 0.12 m
- RMS error = 0.48 m
- Average % error = 5%



FRF bathy lines -
(LARC 27 Oct 99)
tide level of 0.2 m
accounted for

Courtesy of
Z. Williams

Micro-Camera Payload



Features

- Operation

In-flight, fully autonomous flight planning

Interface

- Command
- Video Out

Serial over UAV platform wireless link

Serial over UAV platform wireless link

Electrical

- Supply Voltage
- Power

12 Volts

10 W (typical)

Mechanical

- Size
- Weight

3.25" x 4" x 7"

900 grams / 2 lbs

Video

- Payload Camera

Dual side looking 3.1 megapixel color machine vision imaging modules

Operating Envelope

- Range
- Speed
- Operating Altitude

Limited by UAV platform and available memory

Up to 60 mph

500 – 1500 ft AGL

Data Processing

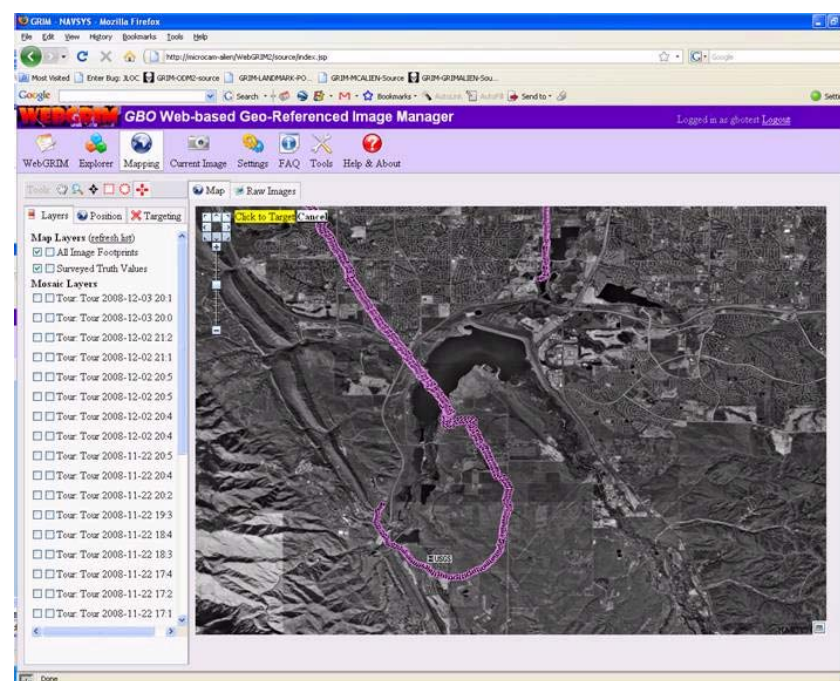
- Bathymetry
- Mapping

Post process data collected over littoral region

Mapping capability from mosaicked imagery

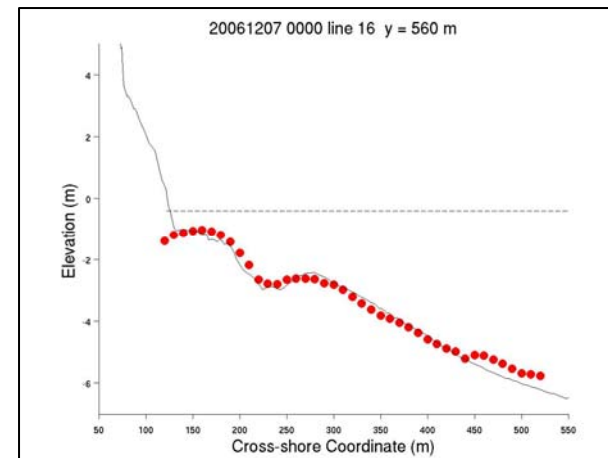
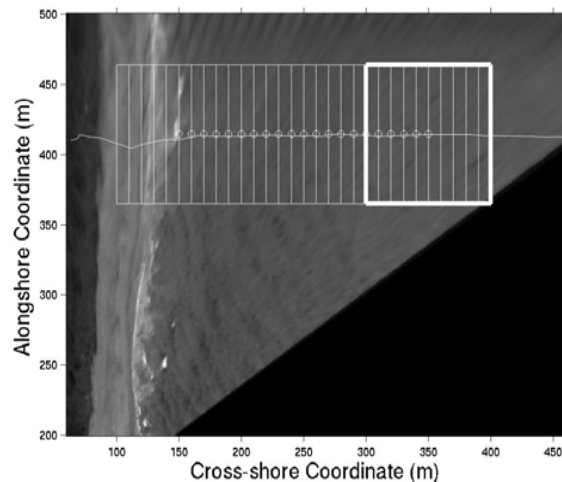
WebGRIM Ground Station Software

- Single, integrated SW environment
- Web Based
 - No new software to install
 - On-line collaboration between multiple users
- Quickly locate and manipulate collected imagery
 - Orthorectification and mosaicking
 - Point and click targeting
- Bathymetry tools
 - UAV Flight planning → Bathymetry map generation
- Compliant with OGC
 - Display third party maps
 - Acts as Web Mapping Service
- Auto-DEM map generation from collected imagery



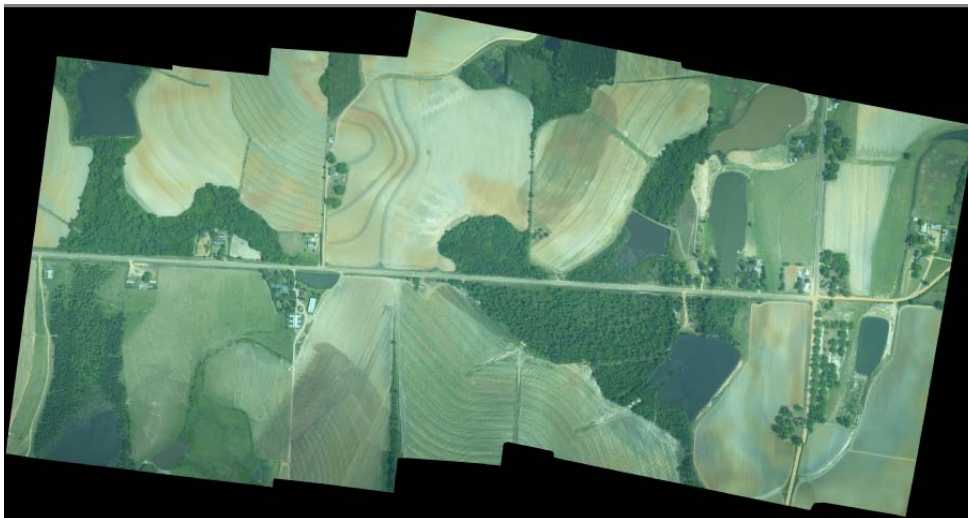
DepthWizard Software

- Software for estimating water depth in shallow regions (0.5 - 30 m) from time series of airborne imagery
- Uses spectral (FFT) inversion techniques based on the physics of surface gravity waves
- Presently MATLAB code; Transitioning to C-coded GUI
- Versatile adaptation to variety of image data



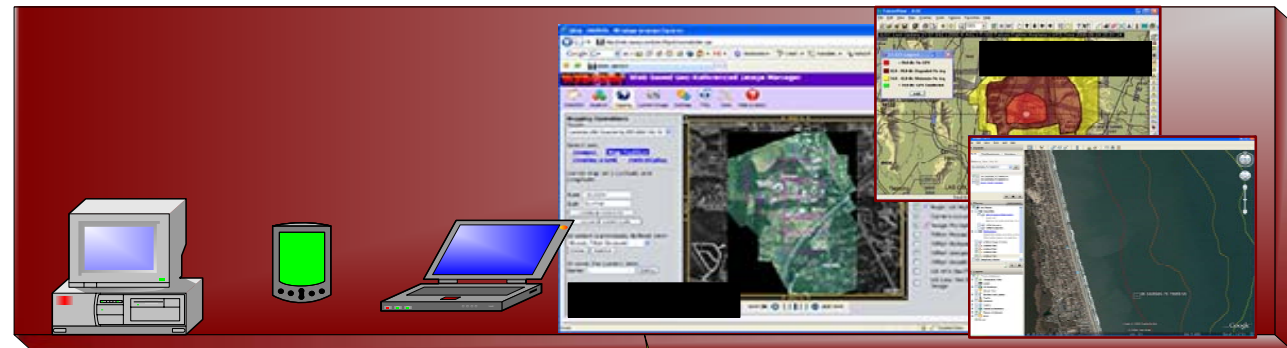
Auto-Mosaicking Results

- Transforms imagery into usable targeting information to facilitate decision making and mission planning



Micro-Camera Ground Station

navsys
CORPORATION



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Duck NC Bathymetry Test Range

- Flight Test & Data Collection w/ Cessna at Duck NC
 - U.S. Army Corps of Engineers Field Research Facility
 - Supports coastal engineering research
- 1000 m of frontage along the Atlantic Ocean
- 1,840 ft research pier
 - 20 ft wide
 - Extends to depth of 20 ft
- (35-ft) tall Coastal Research Amphibious Buggy (CRAB) survey vehicle



Bathymetric Inversion Field Tests

(Duck, NC; USACE Field Research Facility)

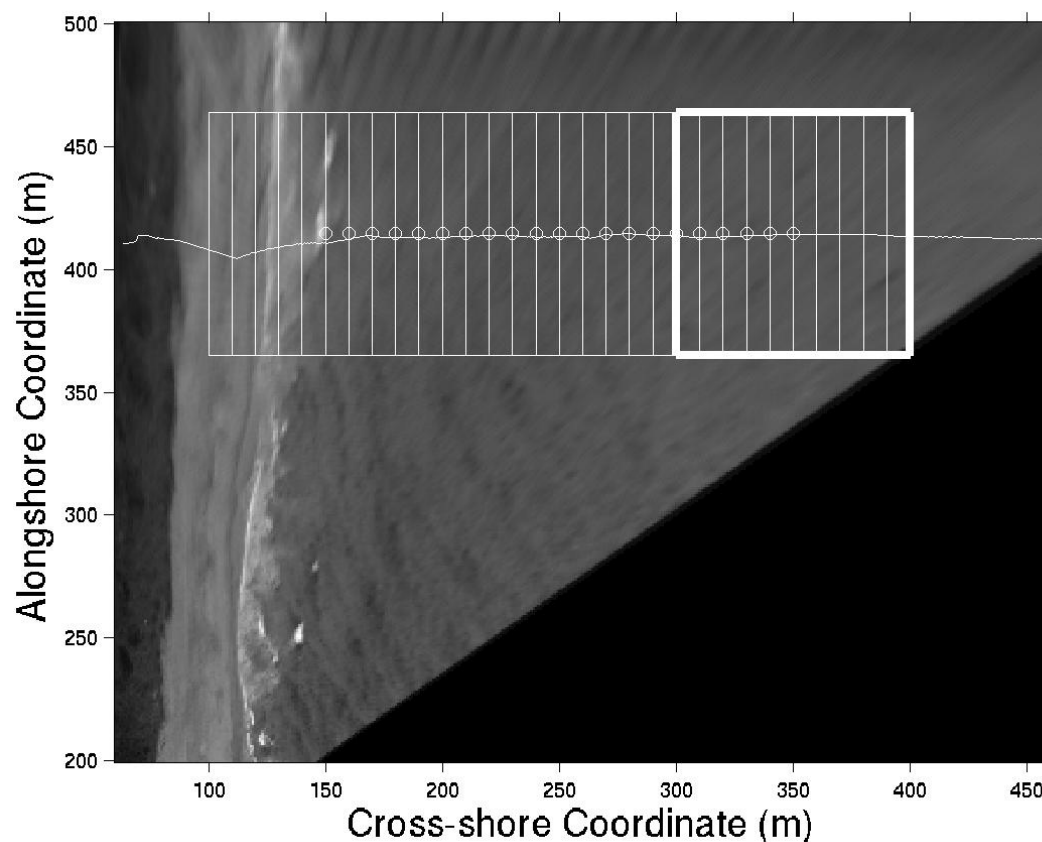


- 27 m above MSL
- High oblique camera view
- 1 MB, 8-bit digital camera
- 3 @ 4 min ensembles

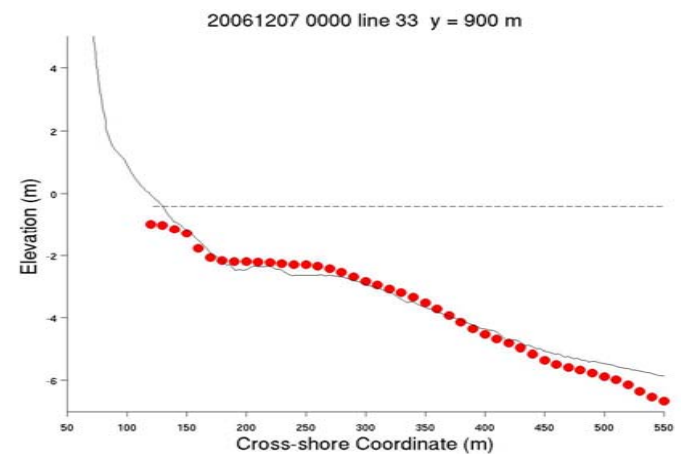
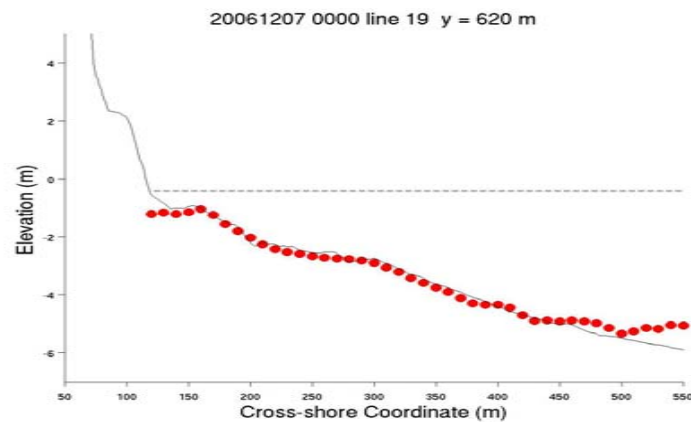
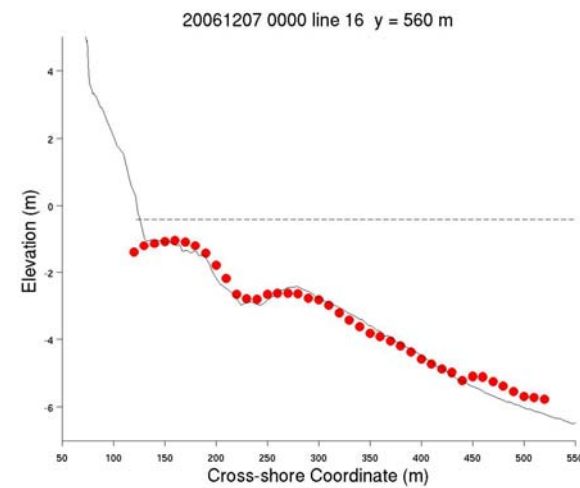
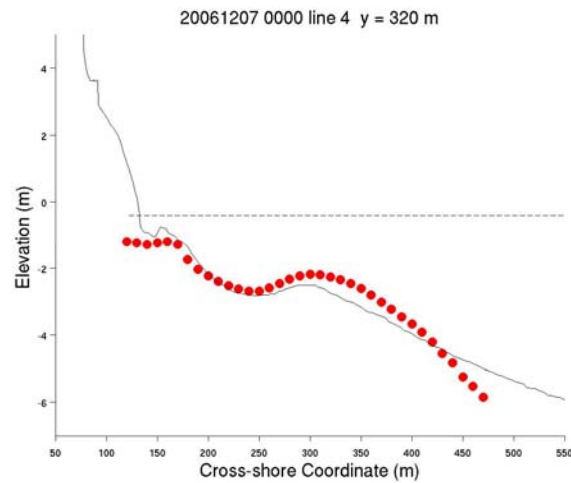


Example Ortho-normalized Snap Shot

- 8 bit deep camera
- 1 m pixel resolution
- Pier structure in center region of image
- Decreasing resolution in the far field owing to high oblique camera view



Profile Comparisons



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Conclusion

- Micro-Camera payload can provide high accuracy meta-data from which we can extract feature coordinates
 - Bathymetry
 - Targeting
 - Mapping
- WebGRIM software can display mosaiced imagery and WMS overlays from Oracle GeoRaster database
 - Geospatial database management provides powerful capability for managing UAS imagery and for search, retrieval and viewing of multi-source data
- Bathymetric inversion methods works reasonably well
 - TOP shore-based techniques, $O(0.5 \text{ m})$ RMS errors in 1-6 m water depths for the 12 days examined
- Validation under variety of conditions not fully completed
 - Small waves only as no ground truth under large waves

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